

THE ONSET OF THE SOLAR ACTIVITY CYCLE 22

H.S. Ahluwalia
Department of Physics and Astronomy
The University of New Mexico
Albuquerque, New Mexico 87131

INTRODUCTION

There is a great deal of interest in being able to predict the main characteristics of a solar activity cycle (SAC). One would like to know, for instance, how large the amplitude (R_m) of a cycle is likely to be, i.e., the annual mean of the sunspot numbers at the maximum of SAC. Also, how long a cycle is likely to last, i.e., its period. It would also be interesting to be able to predict the details, like how steep the ascending phase of a cycle is like to be. Questions like these are of practical importance to NASA in planning the launch schedule for the low altitude, expensive spacecrafts like the Hubble Space Telescope, the Space Station, etc. Also, one has to choose a proper orbit, so that once launched the threat of an atmospheric drag on the spacecraft is properly taken into account. A reboost schedule may also have to be planned for an existing spacecraft threatened by an enhanced atmospheric drag which increases as the solar activity rises. The frequency of reboosts, and the corresponding high accompanying costs, depends upon the amount of drag expected with the rise in the solar activity. For the purpose of proper planning, one would like to have an advance warning of two to three years.

Waldmeier (1935) probably made the first attempt at understanding the behavior of the SAC when he discovered that the steepness of the ascending phase (rise time) of the SAC appears to correlate well with its amplitude, R_m . The steeper the rise, the larger the R_m and vice versa. He also found that even cycles seem to have less steep rise and therefore smaller R_m , whereas odd cycles have a steeper rise and therefore a larger value of R_m . Waldmeier even derived mathematical relations between R_m and the rise time of the odd and even cycles. Attempts have been made to improve Waldmeier's approach (Xanthakis, 1967; Wilson, 1988 and references therein).

In recent times prediction models have been developed based on quasi-physical plausibility arguments. These models rely on a precursor physical signature at the minimum in the previous SAC, such as the geomagnetic and the auroral activity (Kane, 1978) and the solar polar field (Schatten et al., 1978). The methods in this class tend to give a higher value for R_m (Brown and Simon, 1986).

In this paper we explore the possibility of using cosmic ray data for making general predictions about the characteristics of the SAC 22.

DATA AND DISCUSSION

It has been known for many years that an inverse correlation exists between the cosmic ray intensity, at a given site, and the solar activity cycle (Forbush, 1966). The precise physical cause for this long-term modulation of the cosmic ray intensity is not known yet. In recent times, arguments have been advanced that observed 11-year variation may be produced by interacting regions in solar wind (Burlaga et al., 1985), charged particle drifts (Kota and Jokipii, 1983 and references therein), tilt of the heliospheric neutral current sheet (Smith and Thomas, 1986), magnetic helicity (Bieber et al., 1987) and quite possibly by all the processes listed above and some not yet discovered. The reader is referred to an

excellent review on this subject by McKibben (1988). Solar polar fields also appear to play a role in influencing the observed features of the modulation (Ahluwalia, 1980; Jokipii and Kota, 1989).

In Figure 1 we have plotted monthly mean hourly counting rates obtained with a neutron monitor (NM) at Huancayo (Peru) and Deep River (Canada). The median primary rigidities of response for the two detectors are 30 GV and 15 GV respectively. Monthly mean international sunspot numbers (R_i) are also plotted. Data for R_i and Deep River NM cover a period of 30 months from January 1987 to June 1989. Data for Huancayo NM are not yet available for the period March to June 1989. The scale for NM data gives the percent decrease in intensity from maximum intensity observed in March 1987. The following features may be noted.

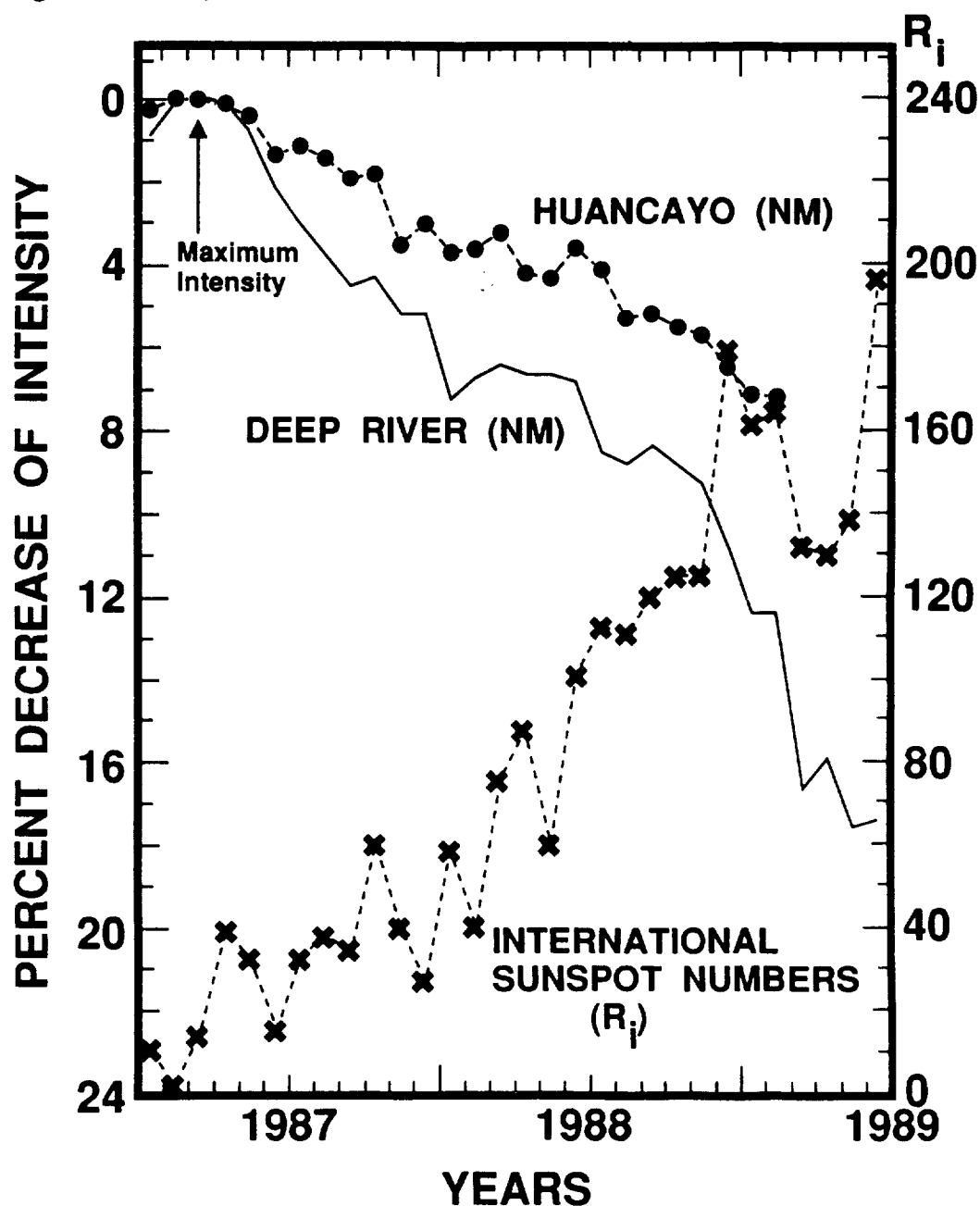


Figure 1.

1) The counting rate for the two neutron monitors decreases continuously after March 1987, as the monthly mean value of the sunspot numbers increases. So an inverse correlation exists between R_i and cosmic ray data. Note that the overall value of R_i increases in a zig-zag manner. The most prominent pulse-like increases in R_i occur in December 1988 and June 1989. However, the counting rate for the Deep River NM keeps going down continuously during this period. For example, the value of R_i in April 1989 is not much different from that in November 1988 but the Deep River NM counting rate has decreased by 6.7%!

2) The counting rates for both monitors begin to decrease simultaneously but the decrease for Deep River NM is steeper. One should also note that the maximum intensity level is attained more rapidly by Huancayo NM. Moreover, the minimum in R_i is reached in June 1986 (not shown) while the counting rates do not recover completely until eight to nine months later. This behavior is typical of cosmic ray modulation (Simpson, 1962).

3) The monthly mean hourly counting rate for June 1989 for the Deep River NM has decreased to a level 17.5% below its level in March 1987. Also note that the value of R_i for June 1989 is 196, the highest observed so far in SAC 22. We may compare this situation with that available in previous activity cycles 21 and 20. For SAC 21, the largest decrease observed at Deep River was 17.9% in September 1982 with respect to the level in September 1976, i.e., the decrease took place over a period of six years. The largest monthly mean value for R_i of 224.3 was observed in October 1981. Similarly during SAC 20, the largest observed decrease of 13.7% at Deep River occurred in June 1969 below the level in April 1965. The largest value for R_i was 135.8 in March 1969. It is clear therefore that activity observed in SAC 22 so far has already exceeded that in SAC 20 and is very close to that observed in SAC 21. Note that the maximum value of R_i has not yet been reached in the present SAC. From cosmic ray data it is clear that SAC 22 is likely to be even more active than SAC 21, although we can't predict yet what the value of R_m will be. This is because quantitative relationships have not yet been established between the cosmic ray data and R_i . But the approach of using cosmic ray data for prediction purposes looks very encouraging. In particular it should be pointed out that after June 1987 it was clear to me that solar activity minimum had already occurred in 1986. It should be emphasized that the observed decrease in Deep River NM counting rate is already close to maximum decrease observed in SAC 21. This decrease has taken place in a very short interval of time (30 months).

We agree with George Withbroe (private communication at this meeting) that SAC 22 is likely to be more like SAC 19. We also agree with Schatten et al. (1987) that SAC 22 will be an exception to Waldmeier (1935) prediction that even activity cycles tend to be less active. However, his basic result is still valid; the rise time of SAC 22 seems to be as steep as that of SAC 19 (private communication from George Withbroe at this meeting). Dicke (1978) suggested that strong sunspot cycles are advanced in phase with respect to the regular ticks of an internal solar clock. It would be nice to explore the implications of this suggestion.

CONCLUSIONS

Cosmic ray data seem to indicate that solar activity cycle 22 will surpass SAC 21 in activity. The value of R_m for SAC 22 may approach that of SAC 19. It would be interesting to see whether this prediction is borne out. We are greatly encouraged to proceed with the development of a comprehensive prediction model which includes information provided by cosmic ray data.

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